

Overview of BNL Nuclear Theory Efforts

Recent personnel changes and staffing plans

Recent science highlights

Synergies with RBRC and HEP theory efforts

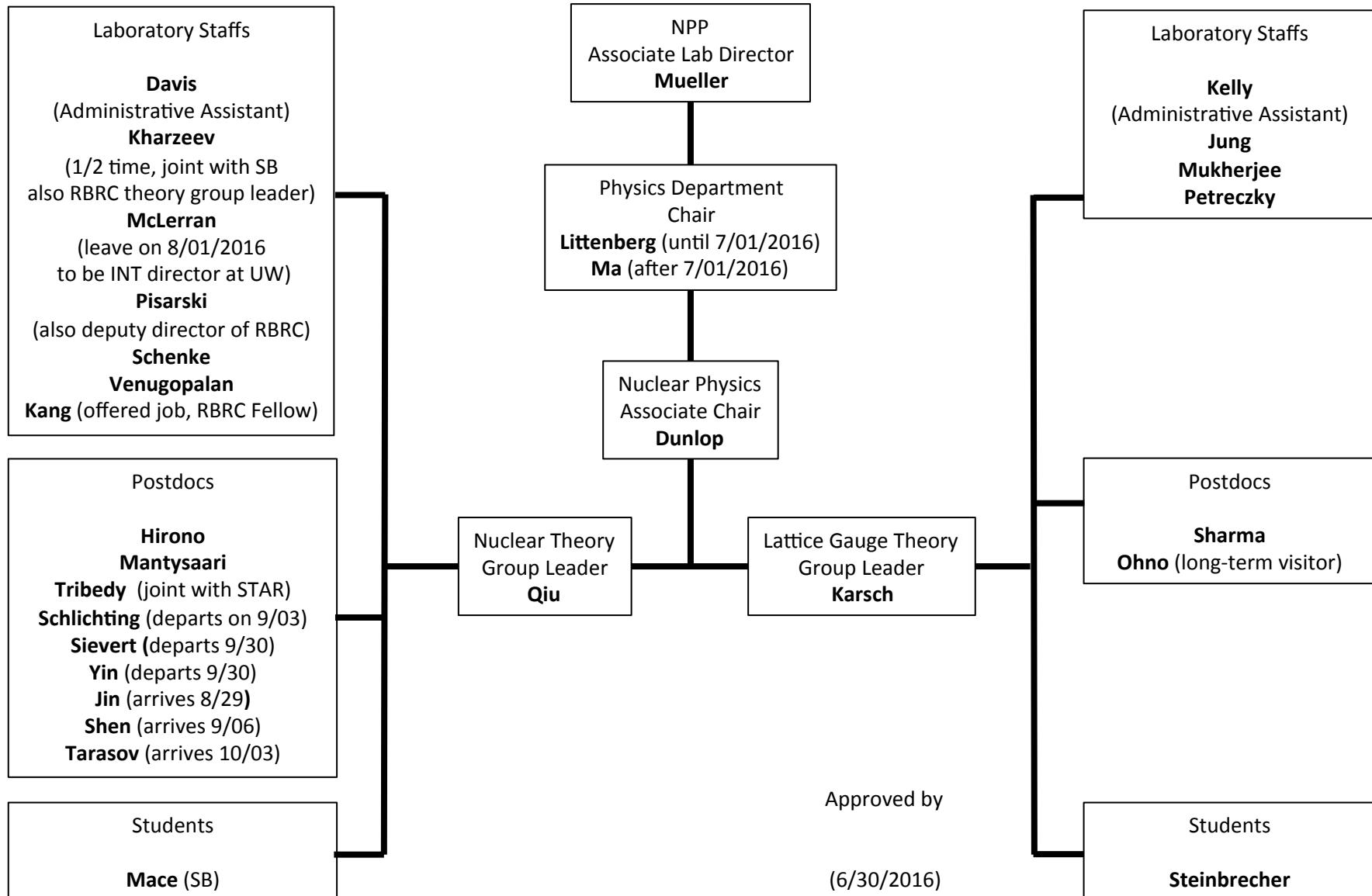
TMD Topical Theory Collaboration

Goals and deliverables

Jianwei Qiu

DOE RHIC S&T Review, August 23-25, 2016

BNL Organization Chart for Nuclear Theory Activities



Nuclear Theory Group (NTG)

Long term Scientific Staff:

D. Kharzeev (joint with Stony Brook)

L. McLerran (INT, UW, since Aug. 1st, 2016)

R. Pisarski

J. Qiu (Group Leader since July, 2015)

R. Venugopalan (Group Leader, 2010-2015)

B. Schenke (Associate Physicist)

Z.-B. Kang (Asst. Physt/RBRC Fellow(offered))

Group Administrator:

Dorothy Davis (80%)

Post-doctoral Fellows:

Y. Hirano (BEST), H. Mantysaari (ECA)

P. Tribedy (35%NT,65%STAR)

S. Schlichting (Goldhaber, leaves 9/3)

M. Sievert (EIC PDF, leaves 9/30)

Y. Yin (Leaves 9/30)

L. Jin (LDRD, arrives 8/29)

C. Shen (Goldhaber-ECA, arrives 9/06)

A. Tarasov (arrives 10/03)

Lattice Gauge Theory Group (LGT)

Long term Scientific Staff:

F. Karsch (Group Leader,
joint with Bielefeld)

P. Petreczky

S. Mukherjee

C. Jung (65%LGT,35%HEP)

Post-doctoral Fellows:

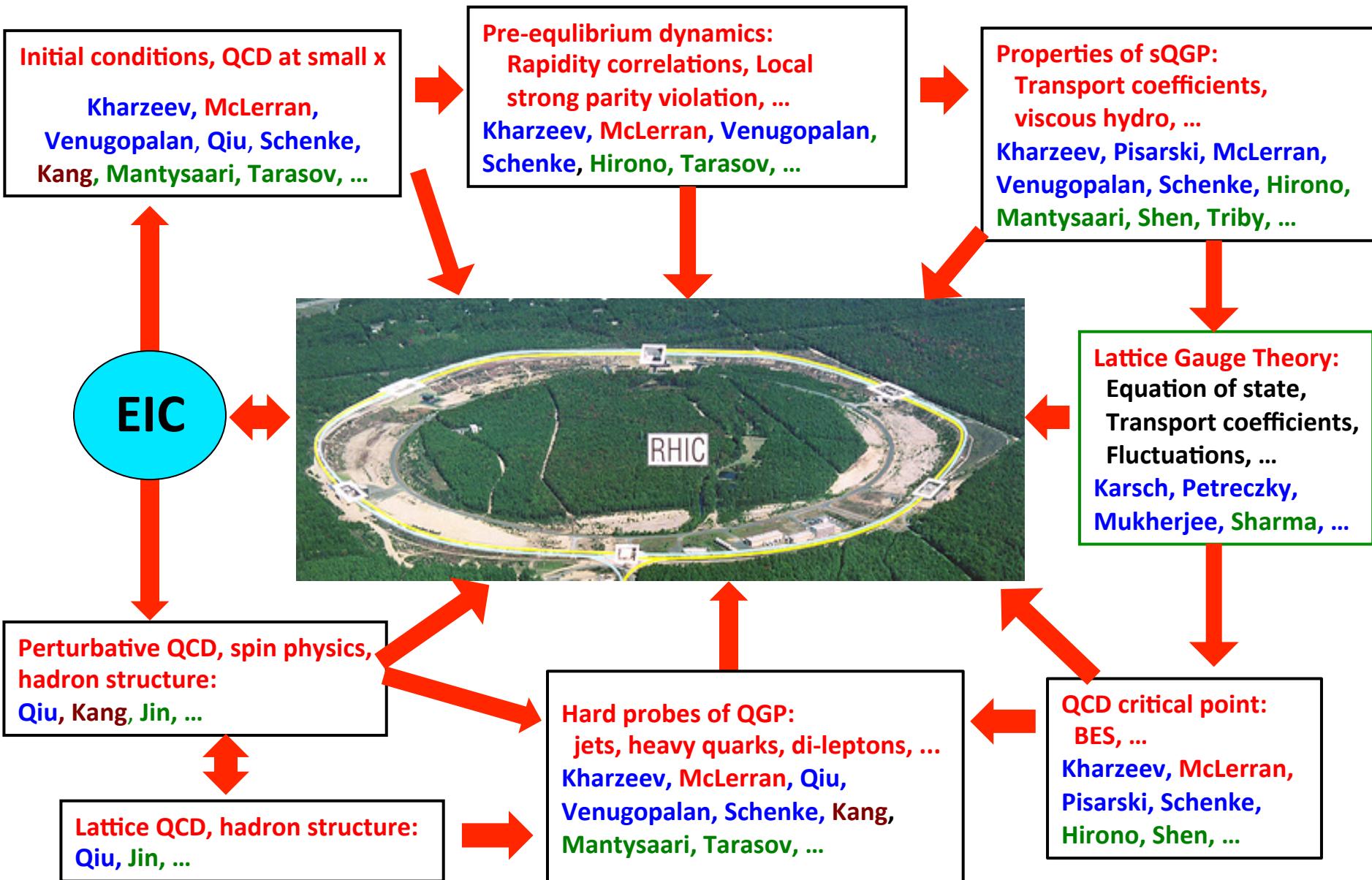
S. Sharma

H. Ohno (Long-term visitor)

Group Administrator:

N. Kelly (35%)

RHIC Physics & Nuclear Theory @ BNL



Recent highlights and plans

Still updating

A quark summary of recent activity

NTG Productivity (May, 2013 - June 2016):

Papers – 124 refereed papers including 25 letters

Invited Talks – 207 invited conference talks, plus colloquia and seminars

From the 5-year proposal submitted for upcoming DOE comparative review

LGT Productivity (May, 2013 - June 2016):

Papers – 35 refereed papers including 7 letters

Invited Talks – 37 invited conference talks, plus colloquia and seminars

NSAC Long-Range Planning process:

QCD Town meeting plenary presentations (Mukherjee, Qiu, Petreczky, Schenke)

Program Committee (Hot QCD, Karsch, Venugopalan; Cold QCD, Qiu)

Major Whitepaper contributions (Karsch, Petreczky, Qiu, Venugopalan)

Resolution Committee (NSAC LRPWG, Venugopalan)

DOE awards for Topical Nuclear Theory Collaborations:

TMD Collaboration – 3D imaging (Qiu – PI&Co-SP, Venugopalan)

BEST Collaboration – BES (Mukherjee – PI, Kharzeev, Schenke, Venugopalan)

A quark summary of recent activity

□ Awards and honors (since May, 2013):

- D. Kharzeev: Humboldt Award (2013), Severo Ochoa Prof., Madrid (2014)
- L. McLerran: APS Feshbach Prize in Theoretical Nuclear Physics (2015),
PhD Honoris Causa at Jagellonian Univ., Krakow, Poland (2015)
- B. Schenke: IUPAP Young Scientist Prize for Nuclear Physics 2013
DOE Early Career Award (2014)
- R. Venugopalan: Research Excellence Prof. Award Heidelberg (2014-16),
EMMI Professorship (2014)

□ Service (since May, 2013):

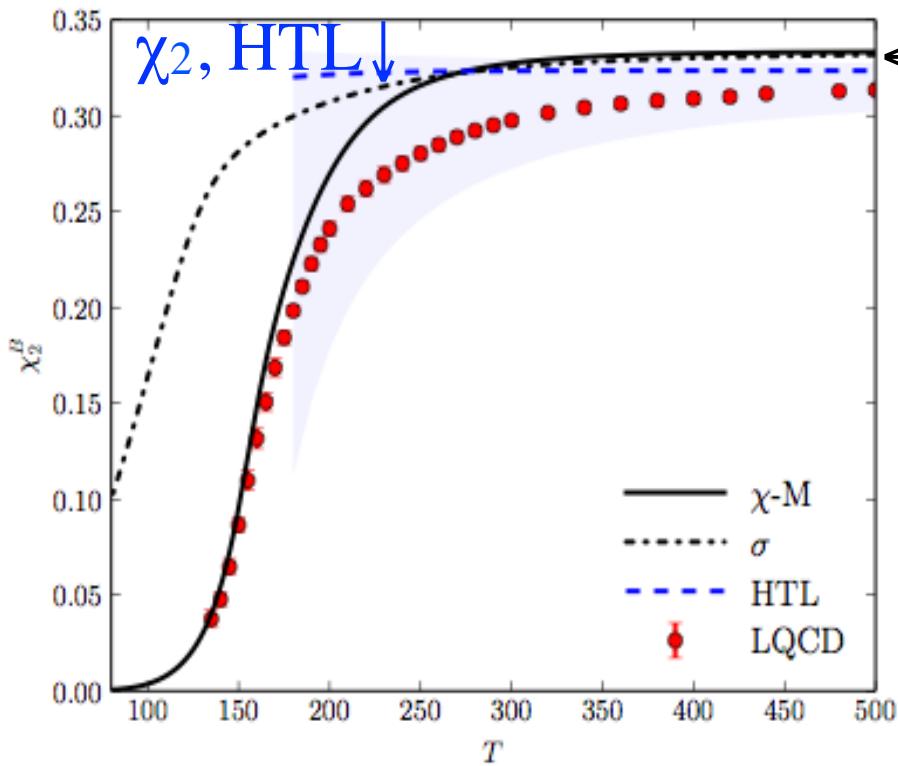
Group members served on International Advisory Committees of numerous major international conferences and workshops, organized many meetings, and lectured at many international summer/winter schools

- F. Karsch: Member of Executive Board of UKQCD
- D. Kharzeev: Program committee of APS/DNP, Editor of Int. J. Mod. Phys. E
- R. Pisarski: Associate Editor of Phys. Rev. D
- J. Qiu: APS Fellow selection committee for APS/GHP (2015)
- R. Venugopalan: NSAC, APS/DNP Executive Committee, Chair APS/GHP (2016)
National Advisory Committee for INT at U of Washington

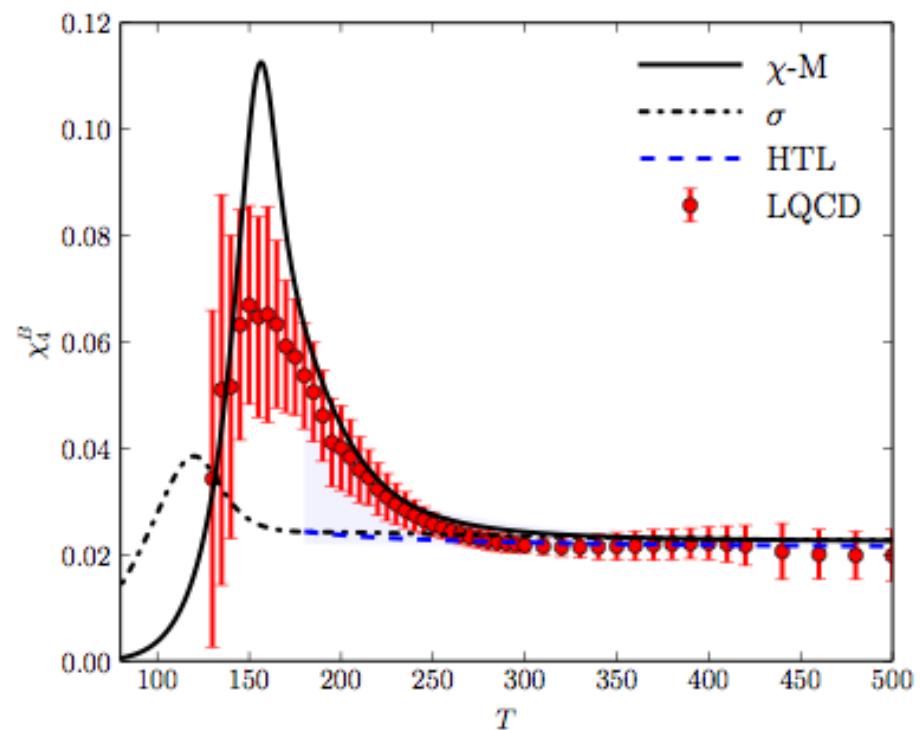
Chiral matrix model, baryon susceptibilities

Matrix model for pure glue + linear sigma model:

$$\chi_n^B(T) = T^{n-4} \left. \frac{\partial^n}{\partial \mu_B^n} p(T, \mu_B) \right|_{\mu_B=0}$$



← χ_2 , model



Two chiral phase transitions from tetraquarks

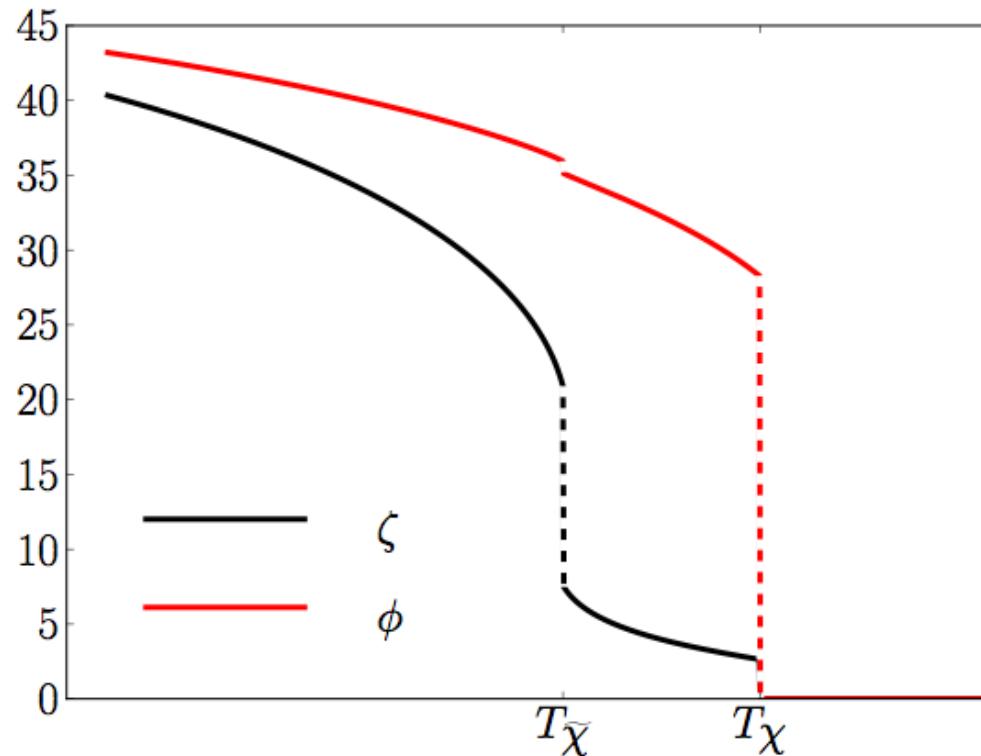
For three light flavors, the tetraquark ζ and usual chiral ϕ transform in the *same* representation of $SU(3)_L \times SU(3)_R$.

Hence tetraquarks *must* be included to understand the QCD phase diagram.

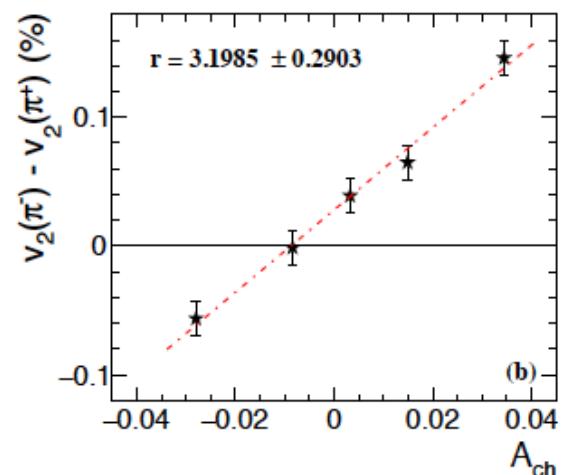
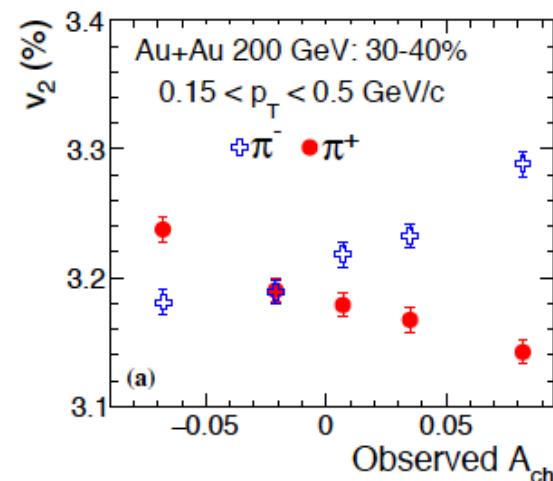
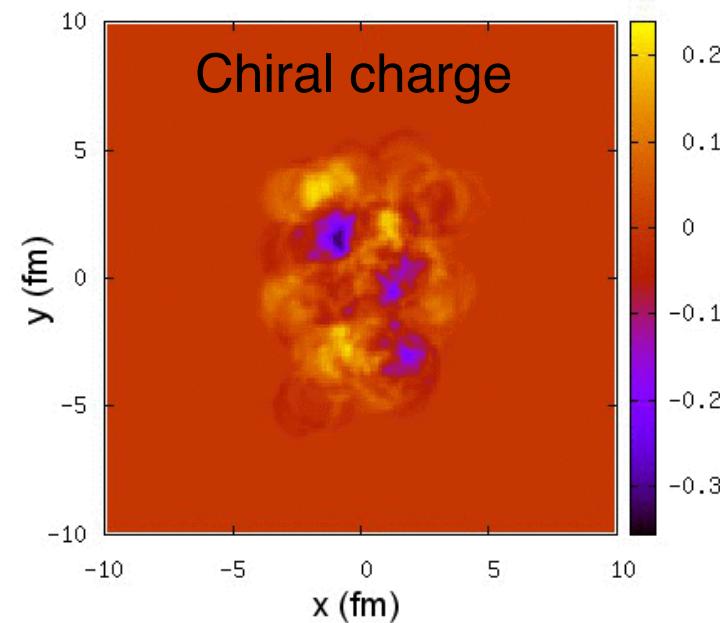
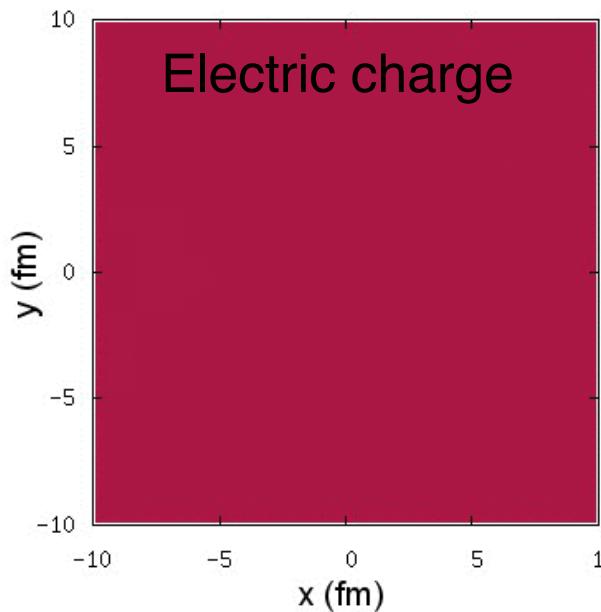
For very light quarks, *may* get two chiral phase transitions.

V. Skokov & RDP:

1606.04111



Chiral magneto-hydrodynamics



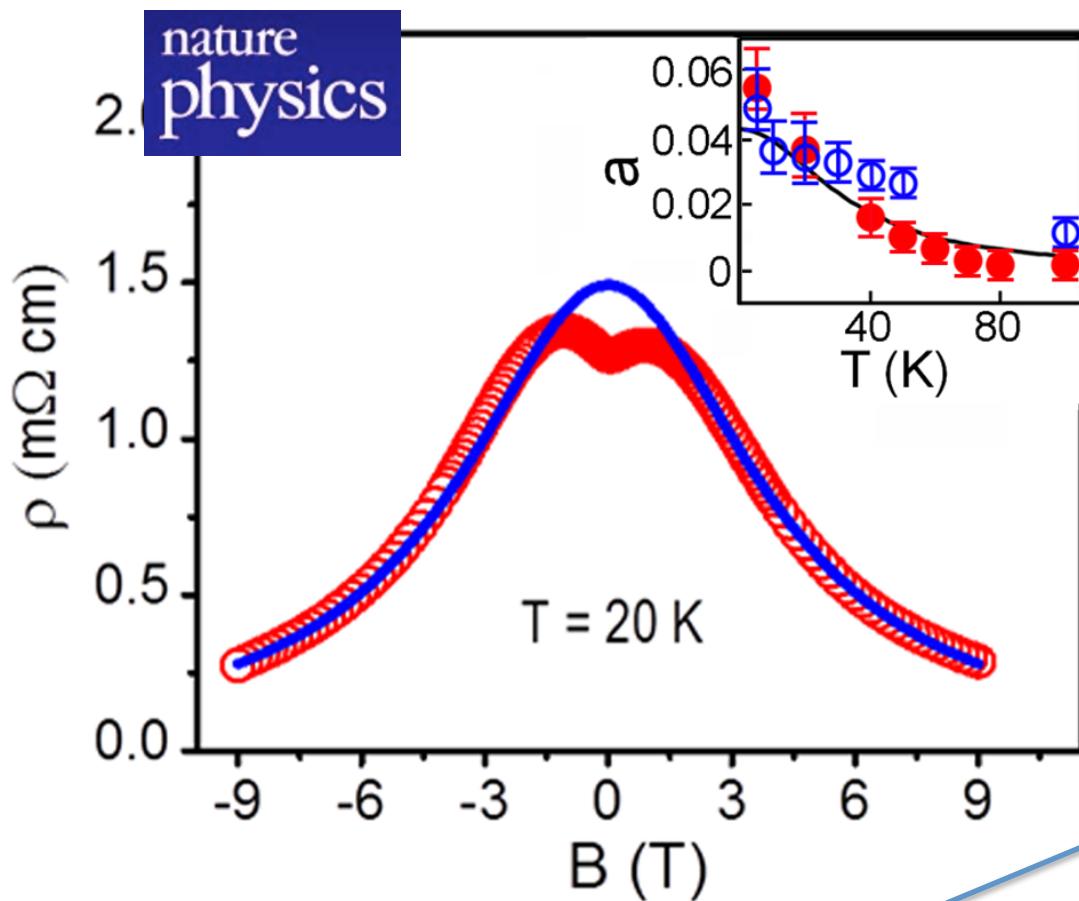
Y.Hirono, T.Hirano, D.Kharzeev,
(3+1) ideal CMHD

BEST Theory Collaboration

Chiral Magnetic Effect Generates Quantum Current

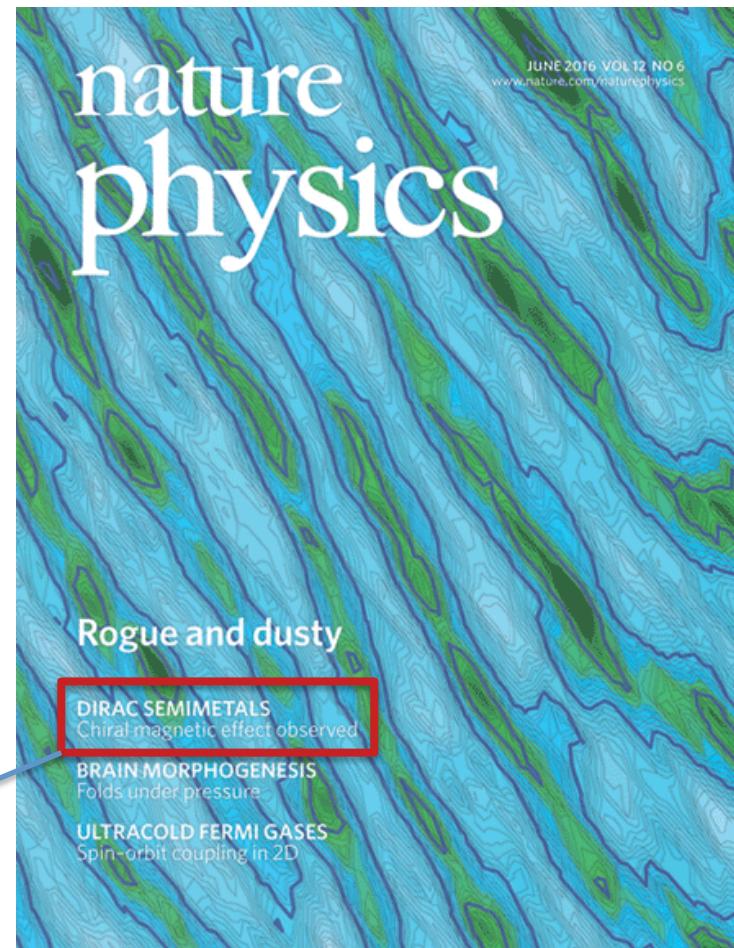
Separating left- and right-handed particles in a semi-metallic material produces anomalously high conductivity

February 8, 2016



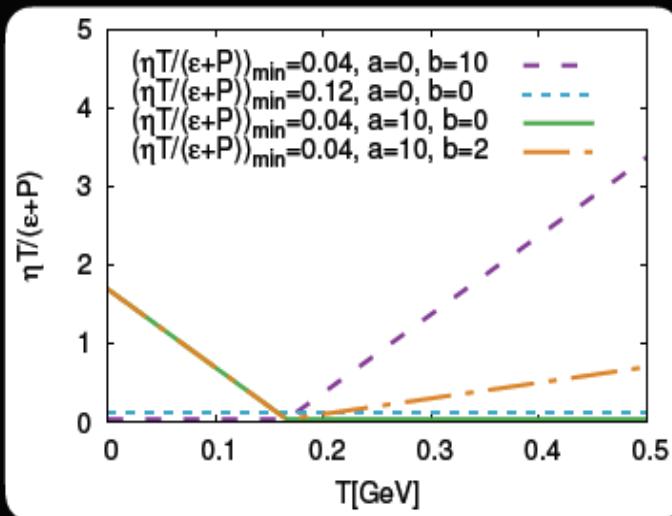
Chiral magnetic effect observed

Q.Li, D.Kharzeev et al,
Nature Physics **12**, 550 (2016)

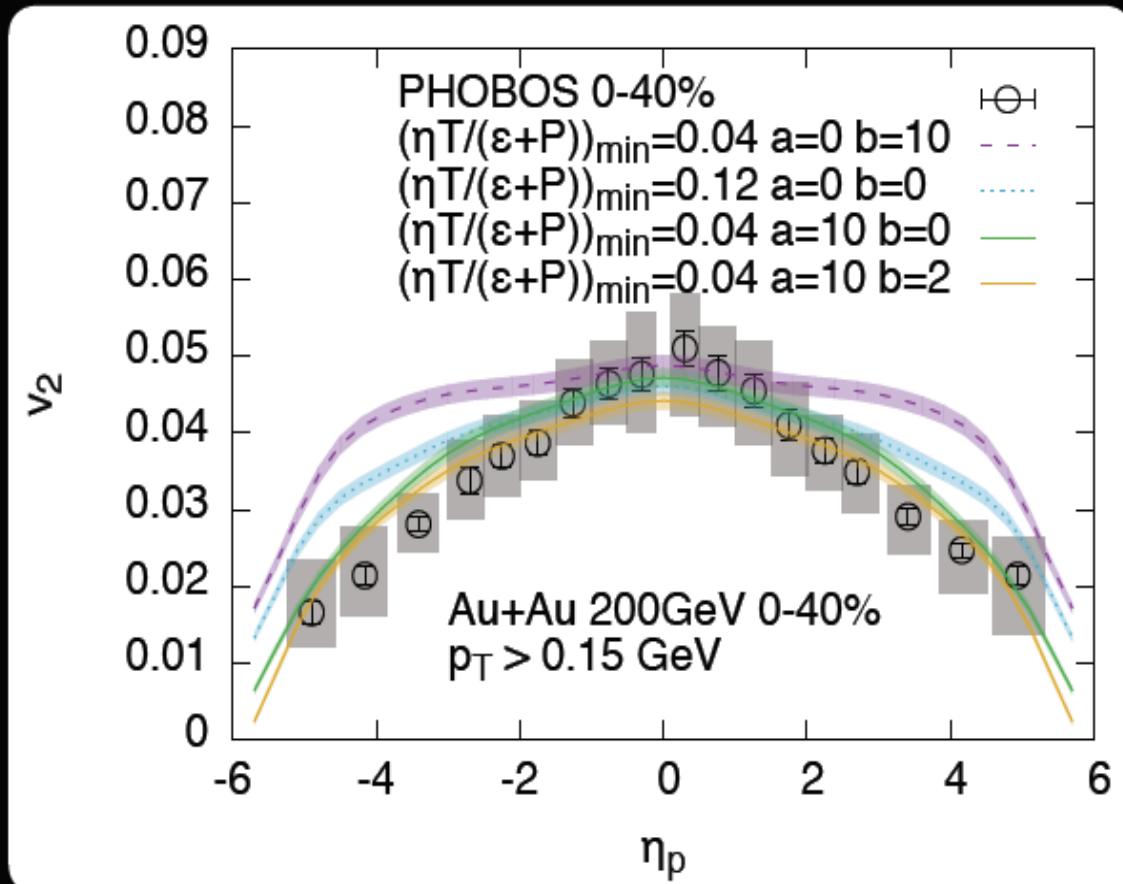


CONSTRAINING η/s VS. TEMPERATURE

G. DENICOL, A. MONNAI, B. SCHENKE, PHYS. REV. LETT. 116, 212301 (2016)



EXP DATA: PHOBOS COLL., B.B.
BACK, ET AL., PHYS.REV. LETT. 94
(2005) 122303



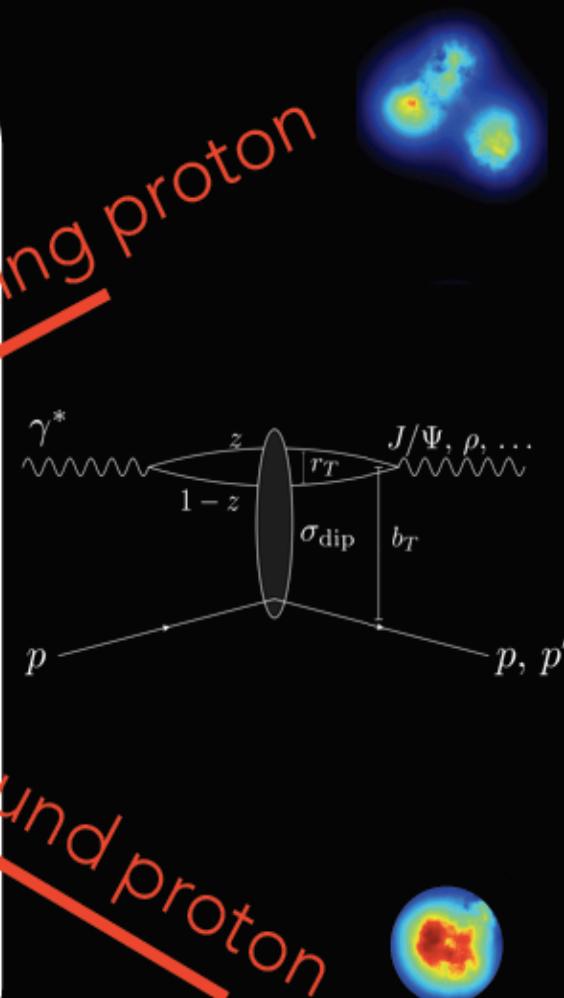
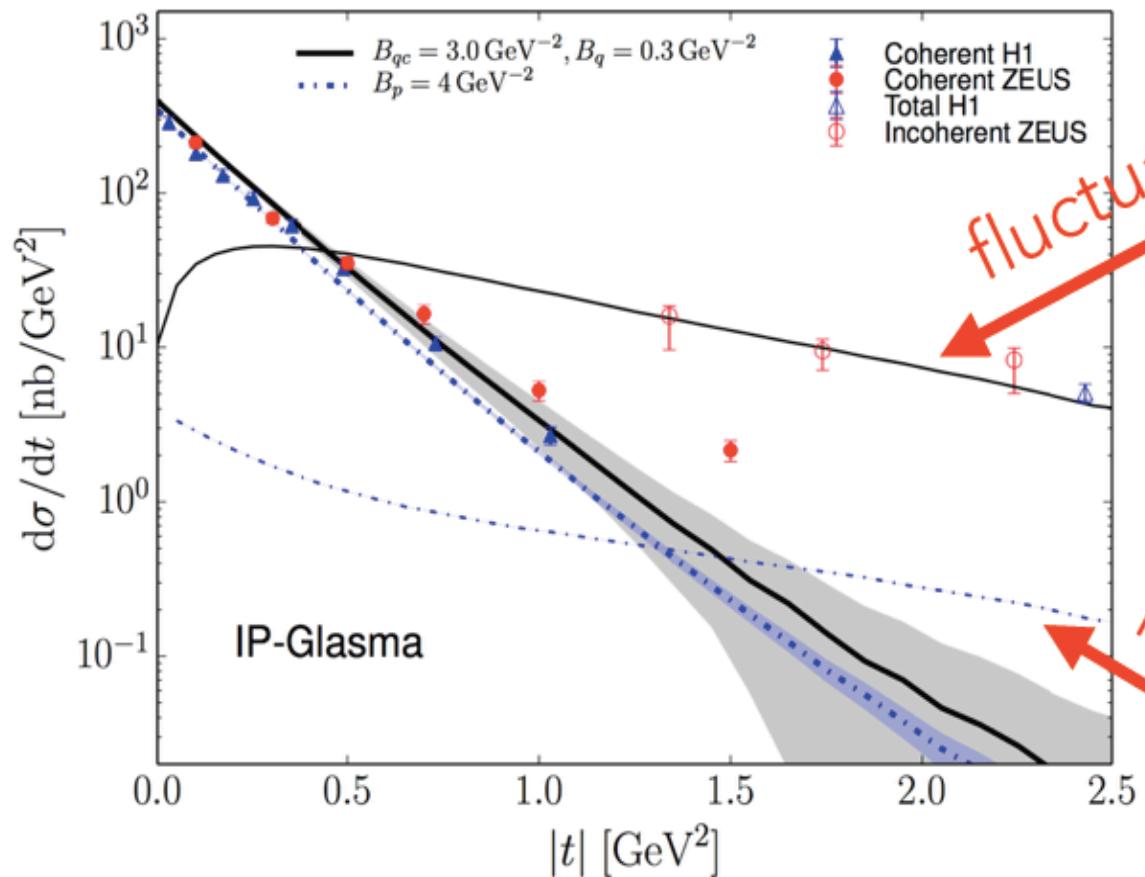
CONCLUSIONS:

η/s IS NOT CONSTANT HADRONIC η/s IS LARGE QGP η/s CANNOT RISE QUICKLY

MORE EVIDENCE FOR PROTON SHAPE FLUCTUATIONS

H. MÄNTYSAARI, B. SCHENKE, ARXIV:1603.04349, PRL IN PRINT

Exclusive diffractive J/Ψ production



CORRELATIONS FROM THE INITIAL STATE

SCHENKE, SCHLICHTING, VENUGOPALAN, PHYS. LETT. B747, 76-82 (2015)

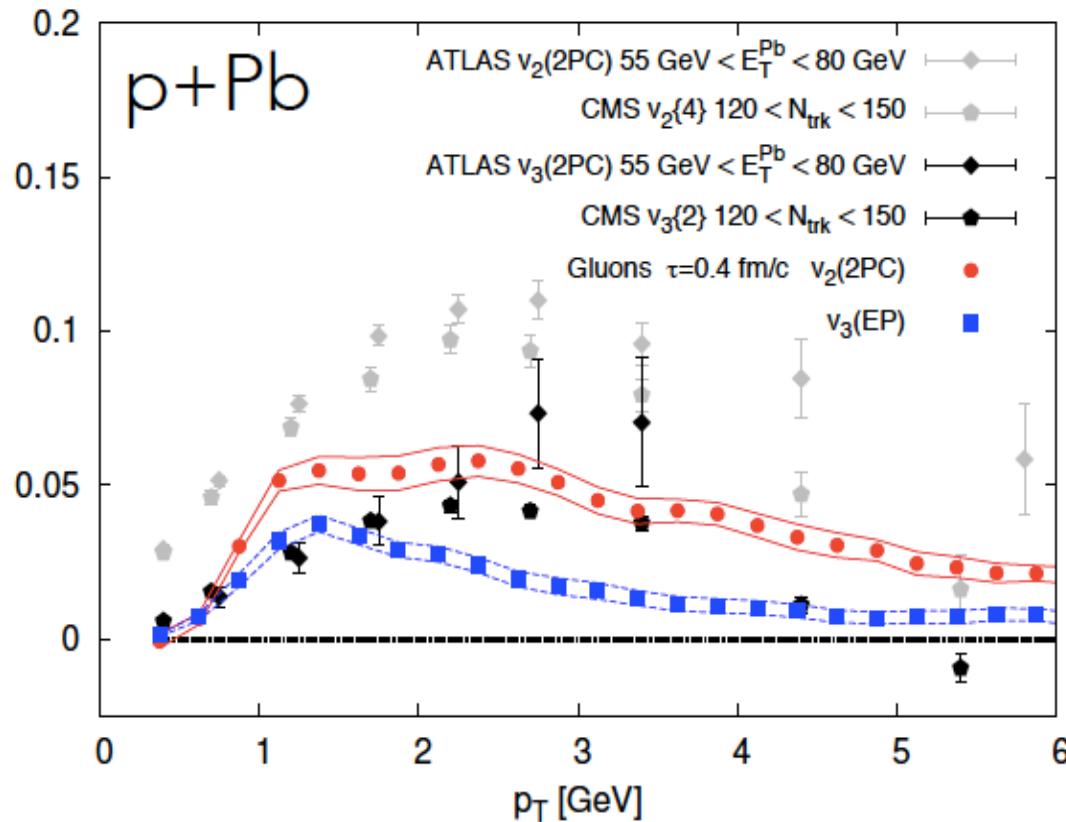
$\tau=0.4 \text{ fm/c}$

gluons

v_2, v_3

data to guide the eye

Fourier harmonics (*event average*)



Odd harmonics generated by pre-equilibrium dynamics

Transverse Spin: Sign change & Evolution

RHIC spin milestone

☐ TMD factorization – Probe confined transverse motion in proton:

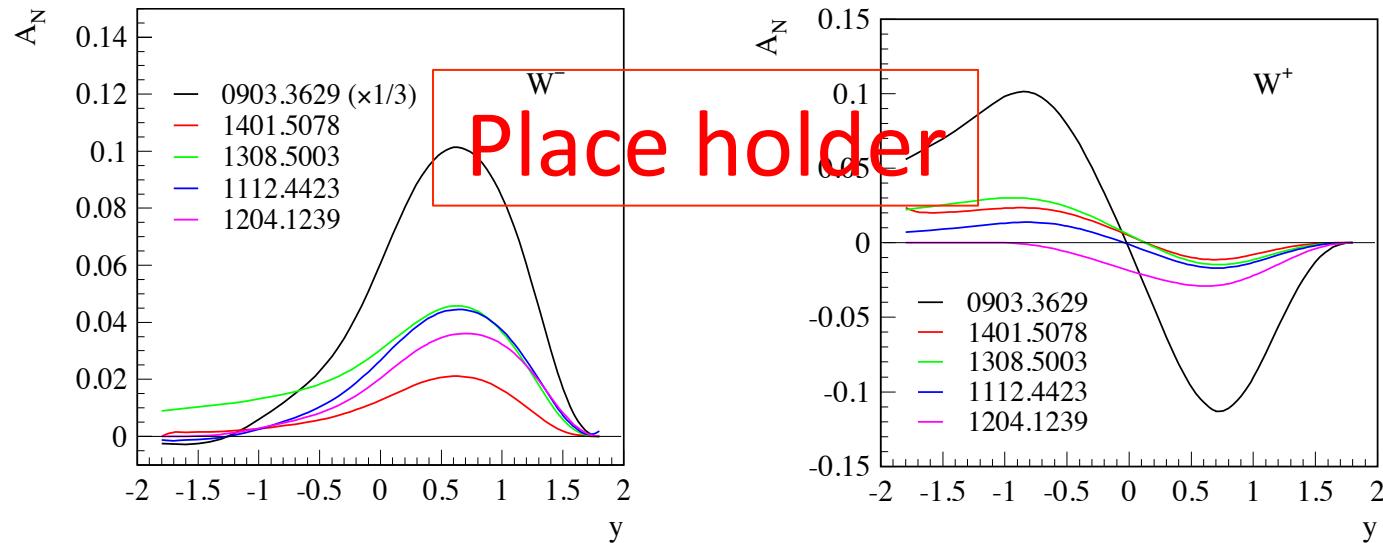
Sivers Effect: hadron spin vs. preference of parton motion

Prediction: Sivers function from DIS = $-$ Sivers function from DY, W/Z, ...

TMDs in nuclei, probing saturation with spin Kovchegov, Sievert, 1505.01176

☐ Current prediction and uncertainty of QCD evolution:

Qiu et al.



TMD collaboration proposal: Lattice, theory & Phenomenology
RHIC is a unique facility to test this ($W/Z - DY$)!

Heavy quarkonium production

□ 1st proof of QCD factorization:

pQCD factorization valid to all powers
In α_s and to leading and NLO pow
in $1/p_T$ but not beyond!

Kang, Qiu and Sterman, PRL108,(2012)

Ma, Qiu, Zhang, PRD89 (2014), 094029, 094030

Kang,Ma,Qiu,Sterman, PRD90 (2014) 034006

Ma,Qiu, Sterman,Zhang, PRL113 (2014) 14, 142002

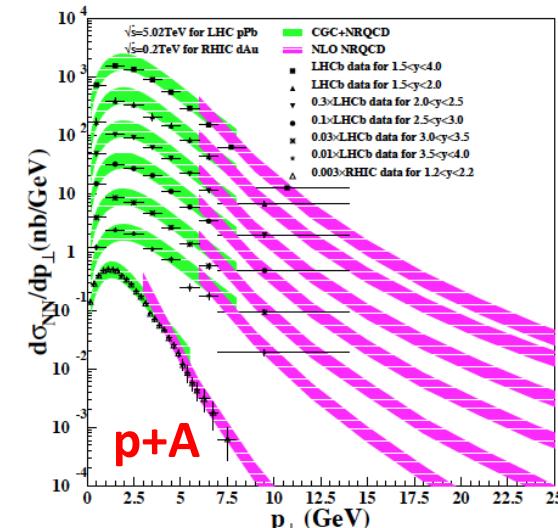
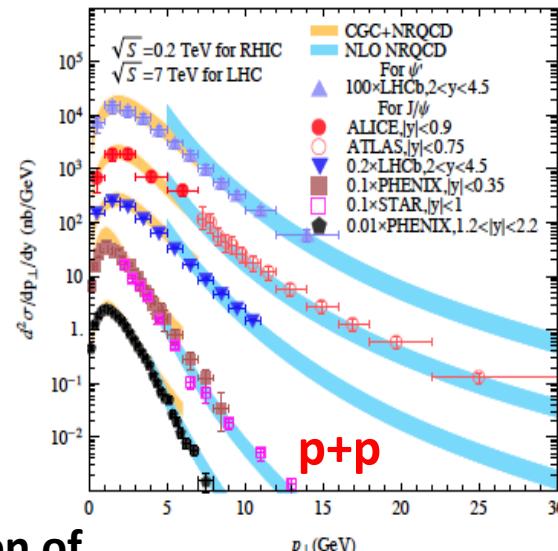
□ CGC & NLO pQCD +NRQCD framework

Kang, Ma, Venugopalan, JHEP 1401 (2014)

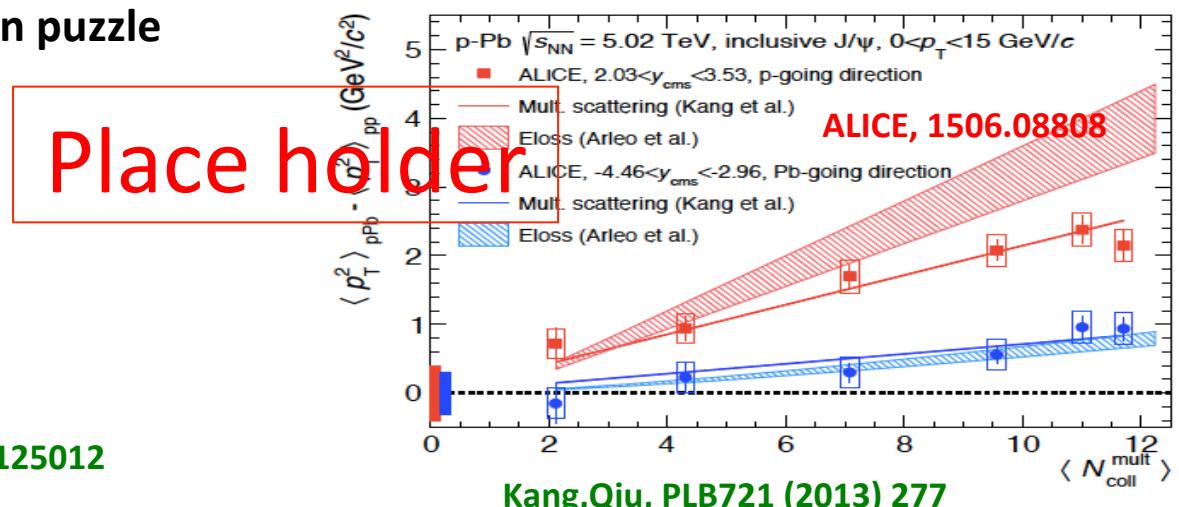
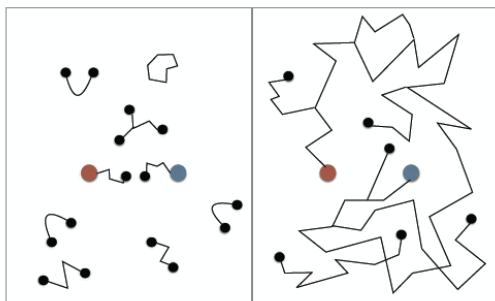
Ma, Venugopalan, PRL 113 (2014) 19, 192301

Ma, Venugopalan, Zhang, 1503.07772

See also, Qiu,Sun,Xiao,Yuan, PRD89 (2014)



□ Entropic dissociation as explanation of A+A RHIC vs LHC J/ψ suppression puzzle



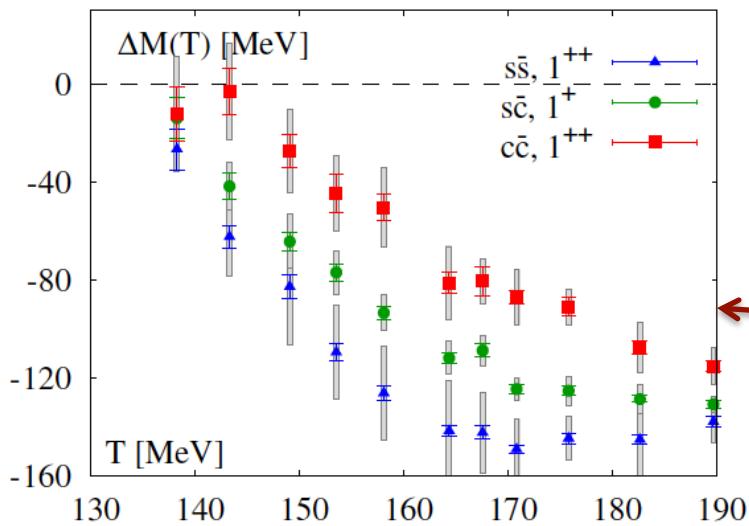
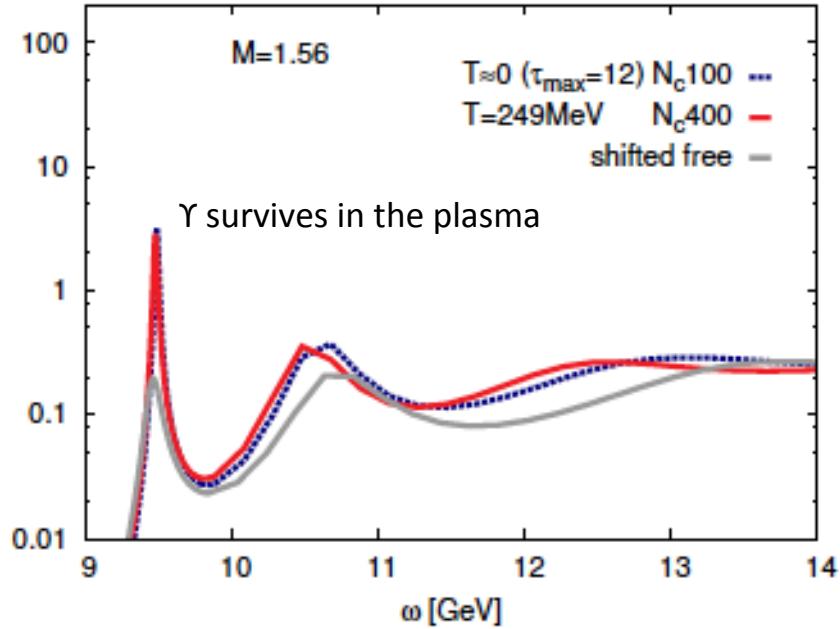
Kharzeev,PRD90 (2014) 7,074007

Hashimoto,Kharzeev, PRD90 (2014) 12, 125012

Place holder

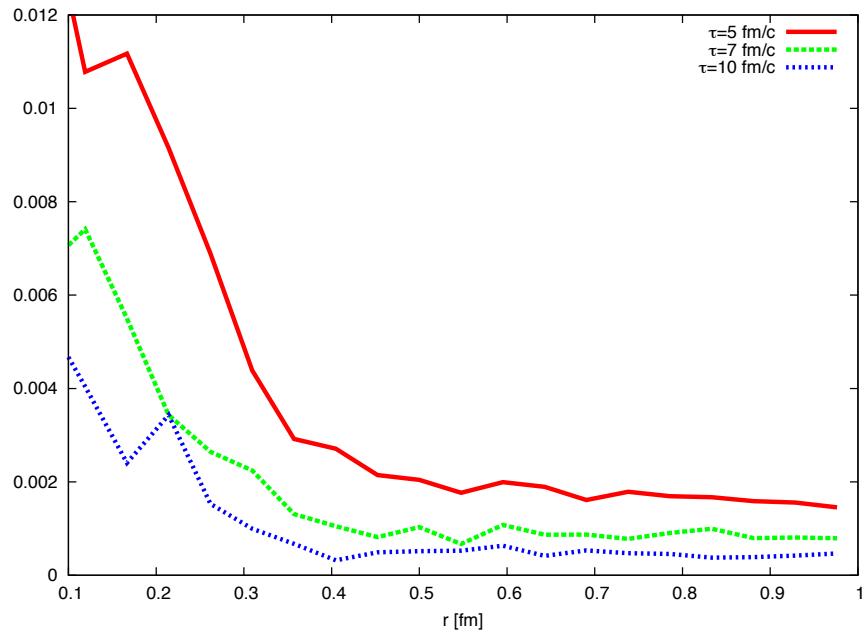
Quarkonium properties and production at T>0

Bottomonium spectral function from lattice NRQCD
 S. Kim, PP, A. Rothkopf, PRD91 (2015) 054511



bb pairs in the hot medium simulated by Langevin dynamics remain correlated even in absence of bound states

⇒ Υ can be formed again in the hot medium
 Petreczky, Young, arXiv:1606.08421 [nucl-th]



Study of spatial charmonium correlators on the lattice
 ⇒ Large shift in the screening mass of 1P charmonia
 ⇒ Sequential suppression pattern
 Bazavov, Karsch, Maezawa, Mukherjee, Petreczky,
 PRD 91 (2015) 054503

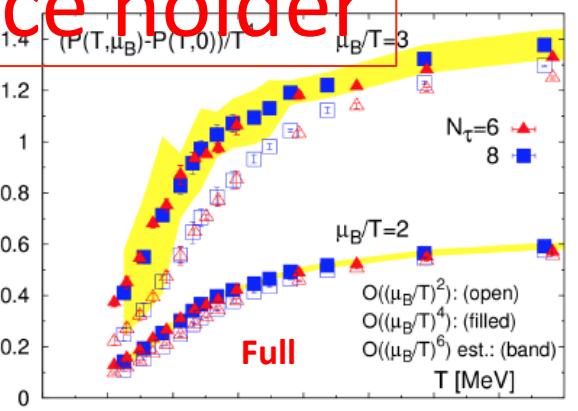
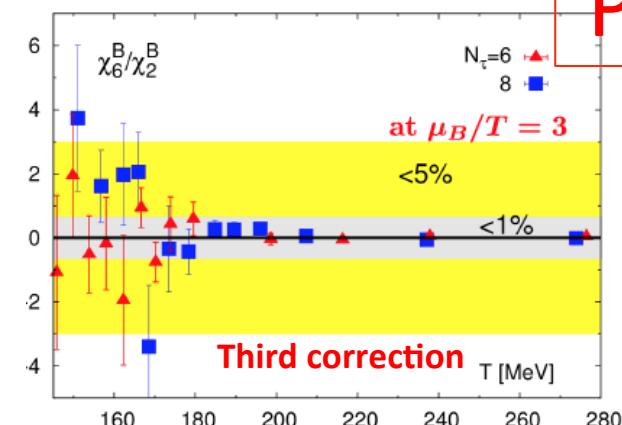
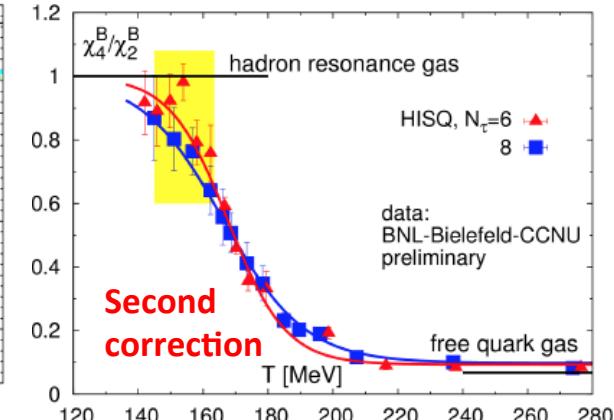
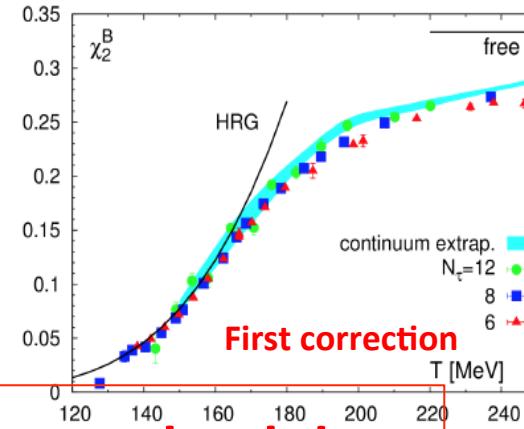
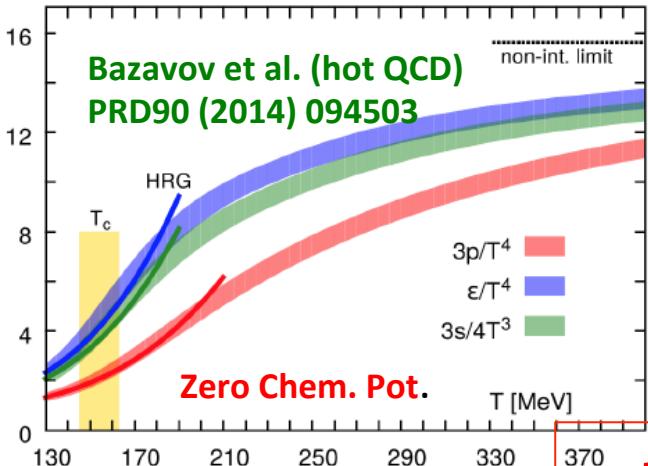
EOS for 2+1-flavor QCD at finite μ_B/T

$$\frac{\Delta(T, \mu_B)}{T^4} = \frac{P(T, \mu_B) - P(T, 0)}{T^4} = \frac{\chi_2^B}{2} \left(\frac{\mu_B}{T} \right)^2 \left(1 + \frac{1}{12} \frac{\chi_4^B}{\chi_2^B} \left(\frac{\mu_B}{T} \right)^2 \right)$$

$$+ \frac{1}{720} \frac{\chi_6^B}{\chi_2^B} \left(\frac{\mu_B}{T} \right)^4$$


LGT,Karsch et al.

estimating the $\mathcal{O}((\mu_B/T)^6)$ correction:



EOS absolutely critical for hydrodynamical modeling



The EoS is well controlled for $\mu_B/T \leq 2$

Synergies with RBRC and HEP theory

□ RBRC theory:

Kharzeev: Head of RBRC Theory Group

Pisarski: Deputy Director of RBRC

Workshops

Interaction and collaboration with Fellows and postdocs

Active participation of RBRC review and planning

□ HEP Lattice effort:

LDRD on lattice QCD effort for hadron structure

Collaboration

Participants: HEP, RBRC, others

Postdocs and students

□ Post-docs:

V. Skokov (**left Sept. 2013, Asst. Prof. at W. Michigan U.**)

Y.-Q. Ma (**left on Aug. 2014, Asst Prof. at Peking U.**)

M. Hentschinski (**left on Sept. 2014, post-doc at UNAM, Mexico**)

G. Denical (**left May, 2016, Junior faculty in Brazilm his home country.**)

S. Schlichting (**leaves on Sept. 3, 2016, Five-year Fellow at U. of Washington**)

Y. Yin (**leaves on September 30, Postdoc at MIT**)

M. Sievert (**leaves on Sept. 30, 2016, postdoc at Los Alamos National Lab**)

LGT group ...

Place holder

□ Students:

H. Zhang (**Ph.D. 2014, Qiu, post-doc at Ohio State U**)

Dima's students ...

M. Mace (**SB student, Kharzeev joint with Venugopalan**)

Budget challenges

NTG+LGT Budget:

Short of ~ 3.5 FTEs – a long term problem in the Group.

Shortfall thus far made up by Physics Dept. and Operations funds

Staffing: Replacement of L. McLerran:

Critical for the program (Spin, EIC, sPHENIX ...)

Group's age distribution, ...

Short-term solution:

Other than those supported by ECA and LDRD, two groups have only one postdoc for each group – LM to support postdocs

Long-term solutions:

Replace L. McLerran by someone who fills in the age gap between Schenke (and Kang) and the rest to have a more balance in demographics and physics

TMD Topical Theory Collaboration

The Collaboration:

Logo here

PI:

Home Institution:

Co-spokesperson:

Participating institutions:

Bridged position, postdocs, students ...

Place holder

Physics objectives – four-fold:

- (1) attempt to devise new and more precise ways to access TMDs at all facilities around the world including the proposed EIC;**
- (2) develop fast software implementations of the extracted TMDs and make them broadly available to the community;**
- (3) pursue non-perturbative lattice QCD calculations of TMDs;**
- (4) provide compelling research, training and career opportunities for young nuclear theorists.**

TMD Topical Theory Collaboration

Deliverables :

Logo here

Milestones

Working groups

Collaborations

Focused workshops

Place holder

Summary

Group is active, productive, ...

Personnel change

Budget

synergies

Back-up slides